Brit.J.Sports Med. — Vol. 21, No. 1, March 1987, pp. 18-21

THE EFFECTS OF MAXIMUM STEADY STATE PACE TRAINING ON RUNNING PERFORMANCE

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ABSTRACT

Maximum aerobic power ($\dot{V}O_2$ max), maximum anaerobic power (AP max), submaximal exercise heart rate (HRsub), and performance times for distances of 15m, 600m, 3.22km, and 10km were evaluated in 12 male runners prior to and after 7 weeks of a running programme at each individual's maximum steady-state (MSS) pace. MSS pace, a runnning speed at which blood lactate is believed to equal 2.2 $mmol.l^{-1}$, was calculated from weekly 3.22 km runs utilising the regression equation of LaFontaine et al (1981). During the training period, the mean MSS pace increased 11.3% from 3.76 to 4.19 $m.s^{-1}$. Body weight and maximal exercise heart rate were unaffected by MSS training. However, MSS training was associated with increases ($p < 0.05$) in absolute $\dot{V}O_2$ max (8.9%) and $\dot{V}O_2$ max relative to body weight (8.1%), absolute AP max (3.7%) and AP max, relative to body weight (4.3%); decreases in resting HR (5.4%) and HRsub (6.9%); and decreases in performance times for runs of 15m (1.8%), 600m (4.4%), 3.22km (9.6%), and 10km (12.1%). MSS paces determined prior to the pre- and post-training 10km races were significantly related to the pre-training ($r = 0.98$) and post-training 10km ($r = 0.95$) performance paces. Pre-training MSS pace, maximal aerobic power, and performance times for the 3.22km and 10km distances were highly related to improvements in MSS pace and performance times for the 3.22km and 10km runs. Our findings indicate that training at MSS pace is an effective method to increase maximal aerobic and anaerobic power, and decrease performance times for short- and middle-distance running events. Pre-training running performance may predict the magnitude of improvement due to MSS pace training.

Key words: Maximal steady state, Pace training, Maximal Aerobic power, Maximal anaerobic power, Running performance

INTRODUCTION

A number of regression equations which establish an individual's maximum steady-state (MSS) running speed have been developed for distances from 3.22 to 20km (LaFontaine et al, 1981). MSS running velocity is defined as the running pace at which the blood lactate is approximately 2.2 $mmol.l^{-1}$, and it has been suggested that the MSS pace is the optimal running speed for training and racing (LaFontaine et al, 1981; Londeree and Ames, 1975). Support for the MSS concept comes from studies in which distance running pace and performance are related to blood lactate levels (Costill et al, 1973; Farrell et al, 1979; Komi et al, 1981; Kumagai et al, 1982) Sjödin and Jacobs, 1981; Williams et al, 1967). However, the effectiveness of training at MSS pace on measures of maximum aerobic and anaerobic power and on performance times for short- and middle-distance running events is not known. At this time, no studies have attempted to evaluate the MSS training concept in a field setting.

Since, it has been reported that MSS pace and performance pace for distances between 3.22km and 16.09km are highly related, we decided to use the MSS equation for 3.22km from a recent investigation to establish weekly MSS training paces (LaFontaine et al, 1981). In addition, the diversified training histories and levels of maximal aerobic power of our subjects allowed us the opportunity to examine how MSS training would effect runners with different performance potentials. Therefore, the purpose of this study was to evaluate the effectiveness of MSS pace training on selected measures of maximal aerobic and anaerobic power and on performance times for short- and middle-distance runs in a group of male runners.

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METHODS AND PROCEDURES

Twelve males, members of a university cross-country team, volunteered to participate in this study. Six of the subjects, designated experienced runners, were well-trained and had a history of sustained aerobic conditioning. Three of these runners had at least three years of continuous high volume training and racing experiences, while the other three subjects had at least one year of high volume training and competitive races. The six remaining subjects were novice or recreational runners who had little to no competitive experience. The physical characteristics and training indices of the subjects are presented in Table I.

TABLE I

Physical characteristics and training indices of the subjects (Mean ± S.D.)

Variables	Groups		
Physical Characteristics	**Experienced (n = 6)**	**Novice (n = 6)**	**Combined (n = 12)**
Age (yrs)	19.3 ± 0.52	22.2 ± 4.1	20.6 ± 3.1
Height (cm)	179.6 ± 5.2	177.2 ± 4.4	178.4 ± 4.7
Weight (kg)			
pre-training	65.00 ± 6.23	70.48 ± 5.37	67.74 ± 6.24
post-training	64.31 ± 5.41	70.06 ± 4.91	67.19 ± 5.77
Training Indices			
Total Workout Distance (km)	905 ± 352	423 ± 349	664 ± 418
Total Workouts (#)	70 ± 7	41 ± 21	56 ± 21
Mean Workout Distance (km)	13.0 ± 5.2	9.1 ± 3.1	11.0 ± 4.6

In this study, MSS pace training was conducted for 7 weeks. During the 10 days prior to the commencement of MSS training, each runner was given a general orientation to the study, and a physical examination from a physician. All subjects completed and signed a form giving their voluntary consent to participate in the research project. Training during this period was voluntary and averaged

4.8km per day per runner with the experienced runners accounting for 66% of this training.

During the 7 week training period, MSS training runs were conducted Monday through Thursday on a 400 metre track and over four different cross-country courses ranging in distance from 4 to 16km. All MSS training runs on the 400 metre track were supervised and running pace was maintained using a large dial field clock. During the initial weeks, training consisted of 400 metre distances run at MSS pace. Latter training sessions progressed to distances between 1.6km to 5km at MSS pace. After each day's MSS pace training on the track, the runners performed additional training runs at or near MSS pace over the cross-country courses. The performance times for the runs were recorded and logged in each runner's training diary.

Each Thursday throughout the 7 week training period, the runners performed a 3.22km run for best time. Individual performance times for the Thursday 3.22km runs were converted to the average running pace ($m.s^{-1}1$) and entered into the 3.22km equasion of LaFontaine et al (LaFontaine et al, 1981): MSS ($m.s^{-1}$) = (17.09 x 3.22km pace) — 54.3; where, MSS and 3.22km pace are in $m.s^{-1}$. In addition, the MSS pace from the Thursday run was used to establish the subsequent week's MSS training pace. Mean 3.22km pace runs and the predicted MSS training paces for all subjects combined prior to training average 4.40 ± 0.67 $m.s^{-1}$ and 3.76 ± 0.76 $m.s^{-1}$, respectively, while after the 7 week MSS training period the values were 4.76 ± 0.53 $m.s^{-1}$ and 4.19 $^{-1}$ ± 0.57 $m.s^{-1}$, respectively. Weekly increases in mean 3.22km and MSS pace averaged 1.16% and 1.61%, respectively. On Fridays, all runners did only stretching exercises in preparation for the Saturday competitive races. Sundays were planned for rest and recovery, however, some of the runners utilised this time for a low intensity workout. Each runner maintained a diary of their training distances and duration for each run.

In our study, maximum oxygen uptake ($\dot{V}O_2$ max) was determined utilising a treadmill test protocol (Bruce, 1971). These tests were conducted between 0800 and 1800 hrs at 22-24°C and 42-54% relative humidity. The peak oxygen uptake for one minute during the test was taken as $\dot{V}O_2$ max. $\dot{V}O_2$ max was expressed as an absolute value ($l.min^{-1}$) and relative to body weight ($\dot{V}O_2$ max-BW, $ml.kg^{-1}min^{-1}$). On a separate day, a submaximal treadmill test was conducted during which the HR response was recorded during a six minute run conducted at 2.77 $m.s^{-1}$ on a horizontal treadmill. Maximal anaerobic power capacity (AP max), expressed in absolute terms as Watts (W) and relative to body weight ($W.kg^{-1}$), was determined during a 40s pedalling test against a 5.5kp resistance on a Monark bicycle ergometer (Katch et al, 1974). A microswitch mounted on the frame and wired to an event marker recorded the total number of pedal revolutions.

All pre- and post-training field performance tests were conducted on a 400 metre all-weather (Chevron 400 surface) track and included the 15m, 600m, 3.22km and 10km run. During the 15m run, the runners were timed as they ran between microswitches after a 50m running start. During the 600m, 3.22km and 10km runs, the subjects were instructed to run as fast as possible utilising the inside lane of the 400m track.

The Wilcoxon matched-pairs signed-ranks test was utilised to evaluate pre- and post-test scores for all test measures (Siegel, 1956). An alpha level of 0.05 was accepted as significant. In addition, Pearson product-moment correlation coefficients were calculated for selected dependent and independent variables.

RESULTS

Resting, submaximal and maximal exercise test values and selected performance times for the experienced and novice runners and for all runners combined are presented in Tables II and III, respectively. During the 7 weeks of training, the MSS training pace increased significantly from 3.76 to 4.19$m.s^{-1}$ (11.3%). There were no statistically significant changes in body weight due to training. For all runners combined (n = 12), resting HR and the HR response to submaximal exercise at 2.77$m.s^{-1}$ were significantly reduced from 55 to 52 $bt.min^{-1}$, and from 145 to 135 $bt.min^{-1}$, respectively, while maximal exercise heart rates were unchanged by MSS training. $\dot{V}O_2$ max-BW was significantly improved by 4.8 $ml.kg^{-1}min^{-1}$ (8.1%), while absolute $\dot{V}O_2$ max was increased by 0.35 $l.min^{-1}$ (8.9%). $\dot{V}O_2$ max-BW increased by 5.8% in the experienced runners and by 11.1% in the novice runners.

TABLE II

Selected physiologic measures prior to and after seven weeks of maximum steady state training in experienced (E) and novice (N) runners and for all and for all runners combined (C). Mean ± S.D.

Variable	Group	N	Pre-Training	Post-Training
HR rest ($bt.min^{-1}$)	C	12	62 ± 7	52 ± 7*
	E	6	59 ± 6	50 ± 6*
	N	6	64 ± 8	55 ± 8*
HR sub ($bt.min^{-1}$)	C	12	145 ± 19	135 ± 20*
	E	6	134 ± 14	125 ± 9*
	N	6	157 ± 18	146 ± 23*
HR max ($bt.min^{-1}$)	C	12	189 ± 8	190 ± 9
	E	6	191 ± 5	190 ± 6
	N	6	188 ± 11	190 ± 8
$\dot{V}O_2$ max ($l.min^{-1}$)	C	12	3.94 ± 0.43	4.29 ± 0.36*
	E	6	4.22 ± 0.27	4.48 ± 0.20*
	N	6	3.65 ± 0.38	4.10 ± 0.40*
$\dot{V}O_2$ max-BW ($ml.kg^{-1}min^{-1}$)	C	12	58.83 ± 9.06	63.62 ± 8.29*
	E	6	65.98 ± 5.92	69.82 ± 4.29*
	N	6	51.68 ± 4.79	57.42 ± 6.10*
AP max (W)	C	12	516 ± 38	553 ± 39*
	E	6	511 ± 15	523 ± 39
	N	6	522 ± 54	546 ± 45*
AP max ($W.kg^{-1}$)	C	12	7.66 ± 0.70	8.00 ± 0.72*
	E	6	7.93 ± 0.85	8.19 ± 0.95
	N	6	7.40 ± 0.44	7.80 ± 0.40*

*Significantly different pre- and post-training, $p < 0.05$

For all runners combined, absolute AP max increased significantly from 516 to 535W (3.7%), while AP max, relative to body weight increased from 7.66 to 8.00 $W.kg^{-1}$ (4.3%). MSS training produced significant decreases in performance times for the 15m run from 1.69 to 1.66s (1.8%), and for the 600m run from 95 to 91s (4.2%). In addition, 3.22km run performance time decreased from 759 to 686s (9.6%), while 10km performance time decreased from 2902 to 2552s (12.1%). For the experienced runners, 3.22km and 10km performance times decreased by 4.3% and 6.7%, respectively, while for the novice runners these decreases were 13.6% and 15.8%, respectively.

TABLE III

Selected performance indicators prior to and after seven weeks of maximum steady state training in experienced (E) and novice (N) runners and for all runners combined (C). Mean ± S.D.

Variable	Group	N	Pre-training	Post-training
15m PT (s)	C	12	1.69 ± 0.09	1.66 ± 0.10*
	E	6	1.73 ± 0.12	1.72 ± 0.10
	N	6	1.66 ± 0.66	1.62 ± 0.07
600m PT (s)	C	12	95.56 ± 8.18	91.32 ± 7.31*
	E	6	92.52 ± 4.66	87.93 ± 3.71*
	N	6	98.62 ± 10.62	94.72 ± 9.25
3.22km PT (s)	C	12	759.33 ± 132.70	686.75 ± 83.68*
	E	6	660.12 ± 46.83	632.00 ± 15.44*
	N	6	858.50 ± 113.78	741.50 ± 89.29*
10km PT (s)	C	12	2902.66 ± 663.42	2552.50 ± 451.33*
	E	6	2385.00 ± 209.88	2225.17 ± 102.94*
	N	6	3420.33 ± 530.16	2879.83 ± 424.73*
MSS pace ($m.s^{-1}$)	C	12	3.76 ± 0.76	4.19 ± 0.57*
	E	6	4.35 ± 0.36	4.56 ± 0.14*
	N	6	3.18 ± 0.56	3.81 ± 0.60*

*Significantly different pre- and post-training, $p < 0.05$

Prior to MSS training, 10km performance pace was significantly related to MSS pace (r = 0.98), $\dot{V}O_2$ max-BW (r = 0.91), and HR_{sub} (r = –0.83). Following MSS training, 10km performance pace remained significantly related to MSS pace (r = 0.95), $\dot{V}O_2$ max-BW (r = 0.89), and HR_{sub} (r = –0.84). In addition, post-training MSS pace was related to mean training pace (r = 0.97) and total training distance (r = –0.69).

Furthermore, pre-training 10km and 3.22km performance time, $\dot{V}O_2$ max-BW, and MSS pace were significantly related to decreases in performance times for the 3.22km and 10km runs and in MSS pace (Table IV), but unrelated ($p > 0.05$) to changes in AP max and AP max.kg^{-1}, and 15m and 600m performance times.

TABLE IV

Significant ($p < 0.05$) Pearson Product Moment correlation coefficients relating changes in maximum steady state (MSS) pace and performance times to pre-training values of $\dot{V}O_2$ max and running performance

Variables*	ΔMSS pace	Δ3.22km time	Δ10km time
$\dot{V}O_2$ max-BW	–0.73	–0.81	–0.86
MSS pace	–0.73	–0.87	–0.90
3.22km time	0.69	0.87	0.87
10km time	0.61	0.79	0.93

*variables represent pre-training values

DISCUSSION

In our study, we found that MSS training significantly improved AP max and $\dot{V}O_2$ max, and performance times for the 15m, 600m, 3.22km and 10km runs. Our findings suggest that MSS training improves both maximal aerobic and anaerobic power, and improves physical performance which utilises a combination of the aerobic and anaerobic energy yielding systems. Thus, our findings provide evidence in support of the concept of MSS pace training.

In addition, we found that maximal aerobic power, MSS for the 3.22km runs, and performance times for the 3.22km and 10km runs prior to MSS training were good predictors of improvement in MSS training pace and improvement in performance times for 3.22km and 10km, but poor predictors ($p > 0.05$) of improvement in the anaerobic (AP max and 15m) and anaerobic-aerobic (600m) performance events. The experienced runners improved their $\dot{V}O_2$ max-BW, MSS training pace, and performance times for the 3.22km and 10km runs by 5.8%, 4.9%, 4.2% and 6.7%, respectively, while in the novice runners these improvements were 11.1%, 20.0%, 13.6% and 15.8%, respectively. Thus, the maximal aerobic power capacity of a runner appears to be an important indicator of the effectiveness of MSS training.

Our findings support the view that endurance training increases $\dot{V}O_2$ max and decreases performance times for distance running events and that the magnitude of improvement of these measures of maximal aerobic power are dependent upon the pre-training level of $\dot{V}O_2$ max. The significant relation between maximal aerobic power and improvement in performance times for the middle-distance running events suggests that MSS training may be more effective for individuals with an initially low level of maximal aerobic power. The increase in running performance of the novice runners was accompanied by increases in $\dot{V}O_2$ max as well as increases in AP max, while the improvements in running performance of the experienced runners was mediated by an increased $\dot{V}O_2$ max. Thus, our findings suggest that this disproportionate effect may be due to the lack of increase in AP max of the experienced runners.

It is known that highly conditioned athletes are able to produce and tolerate higher exercise lactate levels than less conditioned individuals (Åstrand and Rodahl, 1977). In addition, it has been suggested that training at a blood lactate level of 4.0 mmol.l^{-1} is a more appropriate exercise intensity for the improvement of cardiorespiratory functional capacity (Kinderman et al, 1979; Sjödin and Jacobs, 1981; Yoshida et al, 1980). Furthermore, it has been suggested that runners might require "endurance-interval" training programmes equivalent to 90 to 100% of $\dot{V}O_2$ max in order to increase the anaerobic threshold and produce improvements in performance (MacDougall and Sale, 1981). For some runners the LaFontaine 3.22km equation may predict a running pace which is too low of an intensity for optimal gains in cardiovascular endurance. It may be that runners with high maximal aerobic power and a well-established training foundation must work at higher blood lactate values. Additional high intensity "endurance-interval" training which produces higher blood lactate levels may be necessary for those runners who demonstrate little or no improvement with MSS training.

Parenthetically, it must be remembered that the regression equations developed by LaFontaine et al (LaFontaine et al, 1981) are specific for the subjects from which they were derived. Compared to LaFontaine's subjects, our subjects were younger, and more heterogeneous for $\dot{V}O_2$ max and training history. For this reason, prediction of specific MSS running paces from the regression equations of LaFontaine et al should be made with caution. These regression equations should be considered only as general predictors of a MSS training pace.

In conclusion, utilisation of the LaFontaine 3.22km equation to determine MSS training pace can be considered a practical method of determining an individual's training pace for the 10km distance, and as an effective method to increase maximal anaerobic and aerobic performance. However, MSS training for the 10km distance will have its greatest effect on runners with a low VO_2 max, while runners with a high VO_2 max may need to work at a higher level of their maximal aerobic power.

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OBITUARY

Surgeon Captain Charles Boyd Nicholson, CB, MB, BS, DLO, RN (Ret'd)

We were most distressed to learn of the death of Surgeon Captain Nicholson on 23rd November at the age of 84. As a doctor's son he was educated at Epsom School then attended the Middlesex Hospital School of Medicine qualifying with Conjoint in 1926. Almost immediately he joined the Royal Navy and saw service in naval hospitals in Portsmouth, Chatham, Hong Kong and Algiers. After the war he returned to sea but later used his excellent administrative ability to help with reorganisation at the Admiralty. He retired from the Royal Navy in 1958 and was appointed Medical Officer at Eastbourne College.

Nick was a keen sportsman most of his life being an excellent rugby player in his younger days and later a keen and capable golfer. While at Eastbourne College he became a leading member of the Medical Officers of Schools Association and he was a founder member of the British Association of Sport and Medicine since its formation in 1953. It was with regret that we received a letter from him in July, 1986 tendering his resignation with effect from 31st December "as disability and age make me a completely inactive member". He expressed his appreciation of his long term of membership, the many business and scientific meetings he attended and wished the new incorporated Association "warmest good wishes for its future success".

I received a very touching letter from his wife, Peggy, to whom we extend our sympathy — also to his four sons. Nick will be a loss to BASM and to MOSA, especially in his interest in bringing together these two associations. MOSA was also a founder affiliated member of BASM.

H. E. Robson